REON
SACRAMENTO PLANT

REPORT NO. RN-S-0213

TO

AEC-NASA SPACE NUCLEAR PROPULSION OFFICE

CFDTS PRE-TEST PREDICTIONS

APRIL 1965

NERVA PROGRAM | CONTRACT SNP-1

VOLUME II

MASTER

AEROJET
GENERAL TIRE
GENERAL

AEROJET-GENERAL CORPORATION

SACRAMENTO, CALIFORNIA

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AEROJET GENERAL

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CFDTS PRE-TEST PREDICTIONS

VOLUME II

ROCKET ENGINE OPERATIONS – NUCLEAR

NERVA PROGRAM APRIL 1965 CONTRACT SNP-1

NOTICE

AEROJET-GENERAL CORPORATION

A SUBSIDIARY OF THE GENERAL TIRE & RUBBER COMPANY

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SYSTEMS ANALYSIS

COMPONENT DATA FOR CFDTS

The enclosed data represented the best estimate of the performance of the hardware components being used in the CFDTS system at the time of the Pretest Predictions calculations made in March 1965. Where possible, the actual component hardware test acceptance data were used. The data are not necessarily representative of the components being delivered for the NRX/EST or the X-Engines and should not be extrapolated to other systems. The data were used by systems analysis in the current studies of the CFDTS system only and will be upgraded as new information is obtained.

1.0 INTRODUCTION AND SCHEMATIC

A schematic of the CFDTS system is shown in Figure 1. Each of the major components is described analytically by the Systems Analysis and Control Division. The component performance data are presented in the following sections:

2.0 TANK-TO-PUMP LINE

Figure 2 is a schematic of the CFDTS line from the propellant tank to the pump. The design pressure drops for the various components were used to define an overall loss coefficient for the entire line by the following equation:

$$K = \frac{2 g_c \rho A^2 \Delta P}{\dot{w}^2 \, 144} \tag{1}$$

where g_c = gravitational constant = 32.2 $\frac{\text{lbm}}{\text{lbf}} \frac{\text{ft}}{\text{sec}^2}$

ρ = density of hydrogen lbm/ft^3

A^2 = flow area = [illegible] in^2

$\dot{w}$ = design flow rate lbm/sec

ΔP = total design pressure drop from tank to pump

K = overall loss coefficient for line = [illegible].48

Figure 3 presents the line pressure drop as a function of flow rate for various line designs. The present CFDTS line corresponds to that with the Pacific "Y" valve.

References: Source Data Drawing No. [illegible]
RENV Memorandum [illegible]:M2110, dated [illegible] March [illegible]

3.0 TURBOPUMP AND TURBINE

The operating maps describing the Mark III Mod [illegible] pump performance are presented in Figures [illegible] through 10. In Figure 11 are the pump efficiency data supplied to systems analysis, while Figure 12 presents these data as extrapolated and used in the CPDTS analyses. Since the test data were available only for $0.1 \leq Q/N \leq 0.6$, extrapolation was required for pump efficiencies at Q/N values outside of this range. The pump efficiency data in Figure 12 were employed in conjunction with the pump operating maps to define the pump performance over the entire range of parameters.

Figure 13 defines the turbine efficiency over all ranges, the data being evaluated at total-to-static turbine conditions. Since the 12013 program requires the turbine efficiency evaluated at total-to-total turbine conditions, the following conversion was employed:

$$\eta_{t_{TT}} = \eta_{t_{TS}} \left[1 + \frac{k\, R\, T^{\circ}_{x}}{(k+1)(H^{\circ}_{i} - h^{\circ}_{x})} \right]_{I}$$

where:

- $\eta_{t_{TT}}$ = turbine efficiency for total-to-total turbine conditions
- $\eta_{t_{TS}}$ = turbine efficiency for total-to-static turbine conditions
- k = specific heat ratio
- T_{x}° = total isentropic turbine exit temperature, °R
- h°_{i} = total turbine inlet enthalpy, Btu/lbm
- h°_{x} = total turbine exit enthalpy, Btu/lbm
- R = Universal Gas Constant

and the subscript "I" refers to isentropic conditions.

The turbine flow function, $\frac{W_c \sqrt{T_t}}{P_t} = 0.477$

where: W_t = turbine inlet flow, lb/sec

T_t = turbine inlet temperature, °R

P_t = turbine inlet pressure, psia

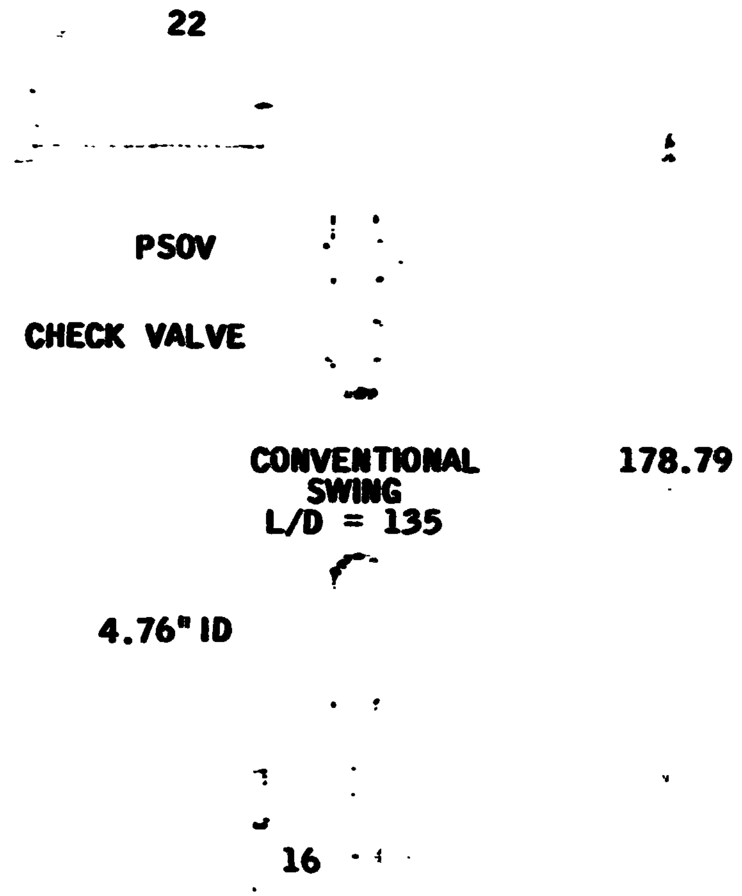
The moment of inertial of the shaft was taken as 487.77 in^2 lbm. (Reference: verbal from P. Soo).

4.00 PUMP DISCHARGE LINE

The pump discharge line is described in Figure 14.

Figure 14

PUMP DISCHARGE LINE



Because the check valve has an opening pressure of 1.7 psia, a constant pressure loss of 1.7 psi was assumed. For the rest of the line, a loss coefficient of 2.83 was used.

References: REON Memoranda 7471:M2110 and 7441:5103M

5.0 NOZZLE

The coolant flow area profile of the S/N-23 nozzle is shown in Figure 15.

Other pertinent nozzle data used to define the CFDTS nozzle model are:

Cold Side		Hot Side	
Inches from Exit	Jacket Thickness, in	Inches from Exit	Area, in^2
0	1.0	0	598.0
2.5	0.625	10.5	356.3
31.5	0.825	21.0	178.0
49.0	0.875	31.5 (throat)	58.8
52.0	2.00	32.0	59.86
53.7	2.00	32.5	62.2
54.9	0.40	33.5	73.14
62.9	0.40	40.0	180.0
		46.4	368.0
		52.9	2198.0
		62.9	2198.0

The U-tube thickness was constant at 0.014 inches.

Reference: REON Memorandum 7456:M2523

6.0 REFLECTOR, SHIELD, SUPPORT PLATE AND CORE

	Reflector	Shield Pass 1	Shield Pass 2	Support Plate	Core
Total Flow Area, in^2	85.0	81.62	68.4	280.8	231.0
Total Wetted Perimeter, in	1432.0	757.5	547.0	3006.0	9531.0
Total Length, in	53.5	11.85	14.0	5.06	53.5
Void Fraction	0.094	0.0817	0.0638	0.31	0.204

Reference: WANL TME-483

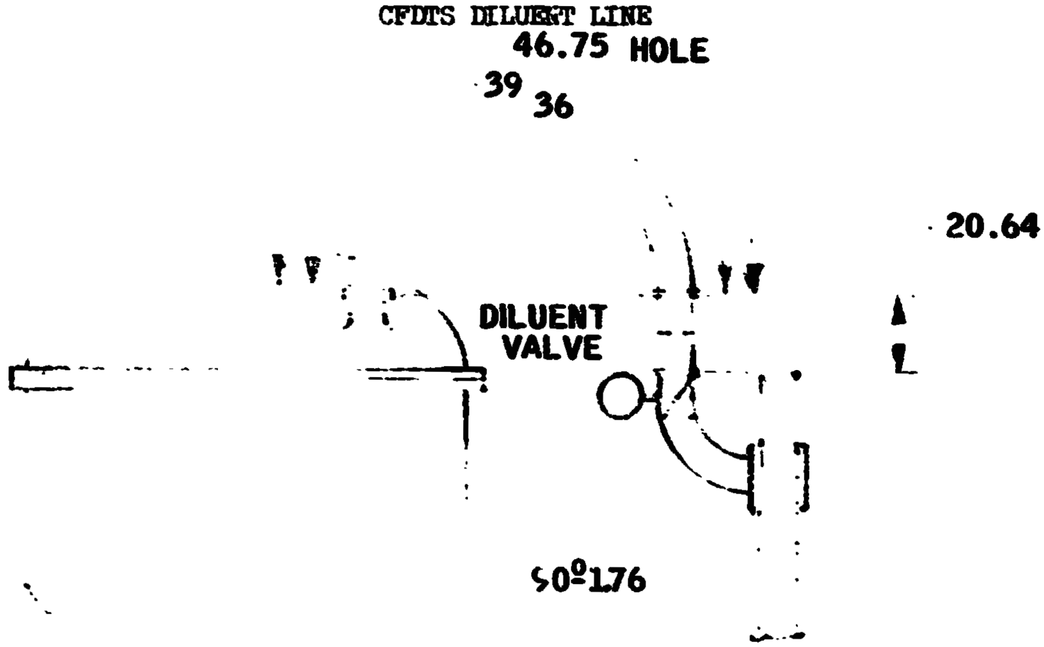
7.0 HOT BLEED SYSTEM

7.1 Diluent Bleed Line

Figure 16 presents the CFDTS diluent bleed line description.

Figure 16

CFDTS DILUENT LINE



This line was calculated to have a loss coefficient of 10.71. Diluent valve is considered wide open with the C_v of 200 being included in the loss coefficient.

7.2 Hot Bleed Port and Jacketed Line

The dimensions used to define the CFDTS hot bleed port and jacketed line appear in Figure 17. Figure 18 presents the loss coefficients used for each segment of this component. For the bleed port the experimental loss coefficient from the flange to the upstream side of the injection holes was found to be 36.8. The loss coefficients are indicated on Figure 18.

There are 630 injection holes, 0.100 inch ID. The hot side of the jacket line is 120 inches long, 3.87 inch ID. The friction factor is 0.004. The mixing orifice in the hot bleed port has a loss coefficient, as defined by Equation (1), of 2.025.

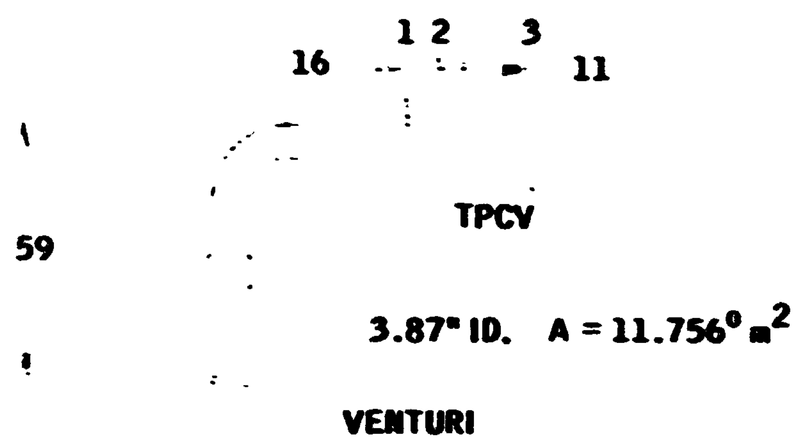
Reference: REON Memorandum 7471:M2110

8.0 TURBINE INLET LINE AND TPCV

The turbine inlet line for CFDTS appears in Figure 19.

Figure 19

TURBINE INLET LINE



For the line up to the TPCV a loss coefficient, defined by Equation (1), of 3.18 was used. A similar loss coefficient of 0.043 for the line from the TPCV to the turbine was used.

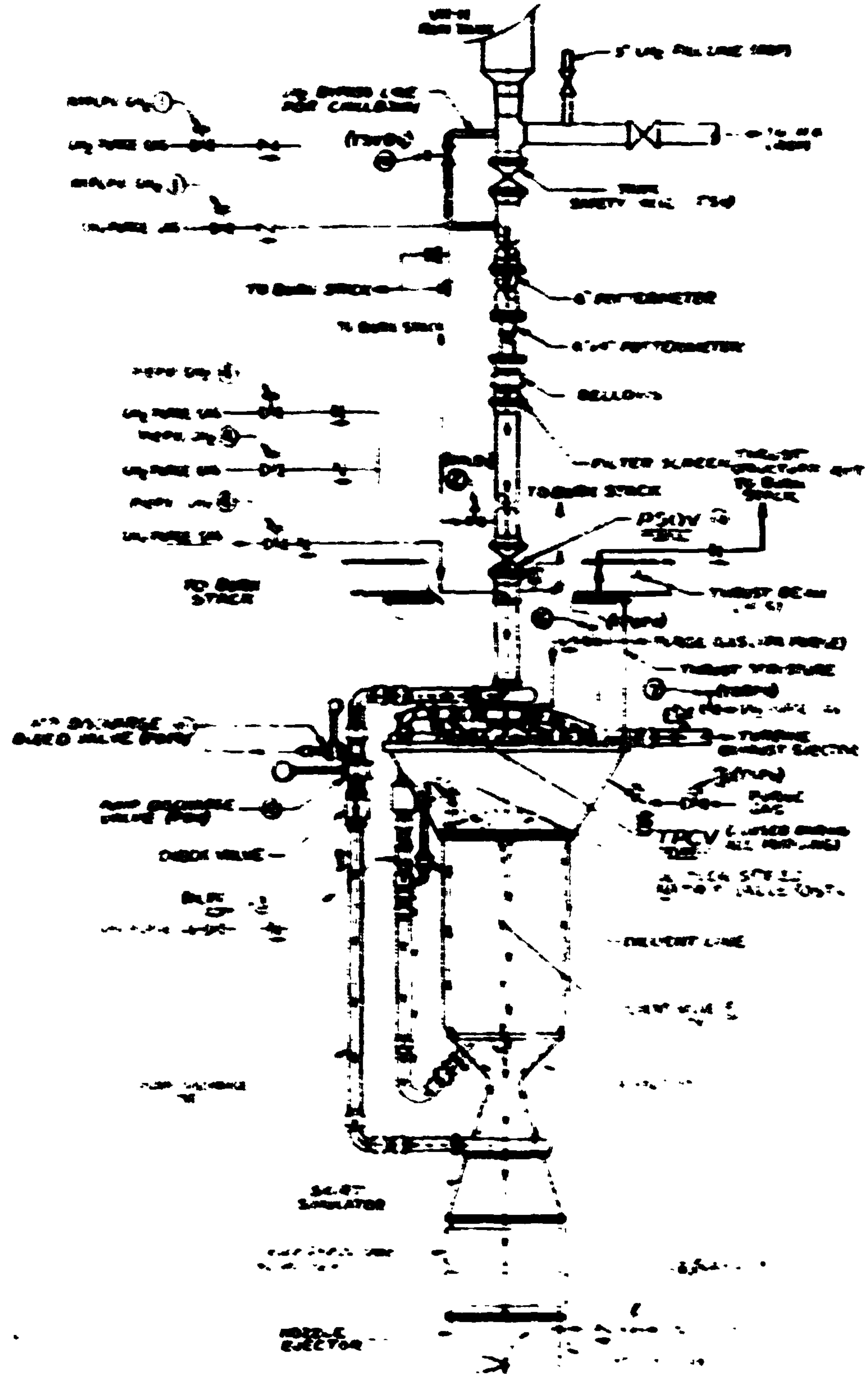
The loss coefficient for the TPCV as a function of the gate position appears in Figure 20.

Reference: REON Memorandum 7471:M2110

9.0 ROLL NOZZLES

Each CPDTS roll nozzle has a throat diameter of 3.09", giving a total throat flow area of 15 in^2.

Reference: R.ION Memorandum 7441:5103M



SCHEMATIC DIAGRAM
[illegible] ENGINE VALVES AND
[illegible]

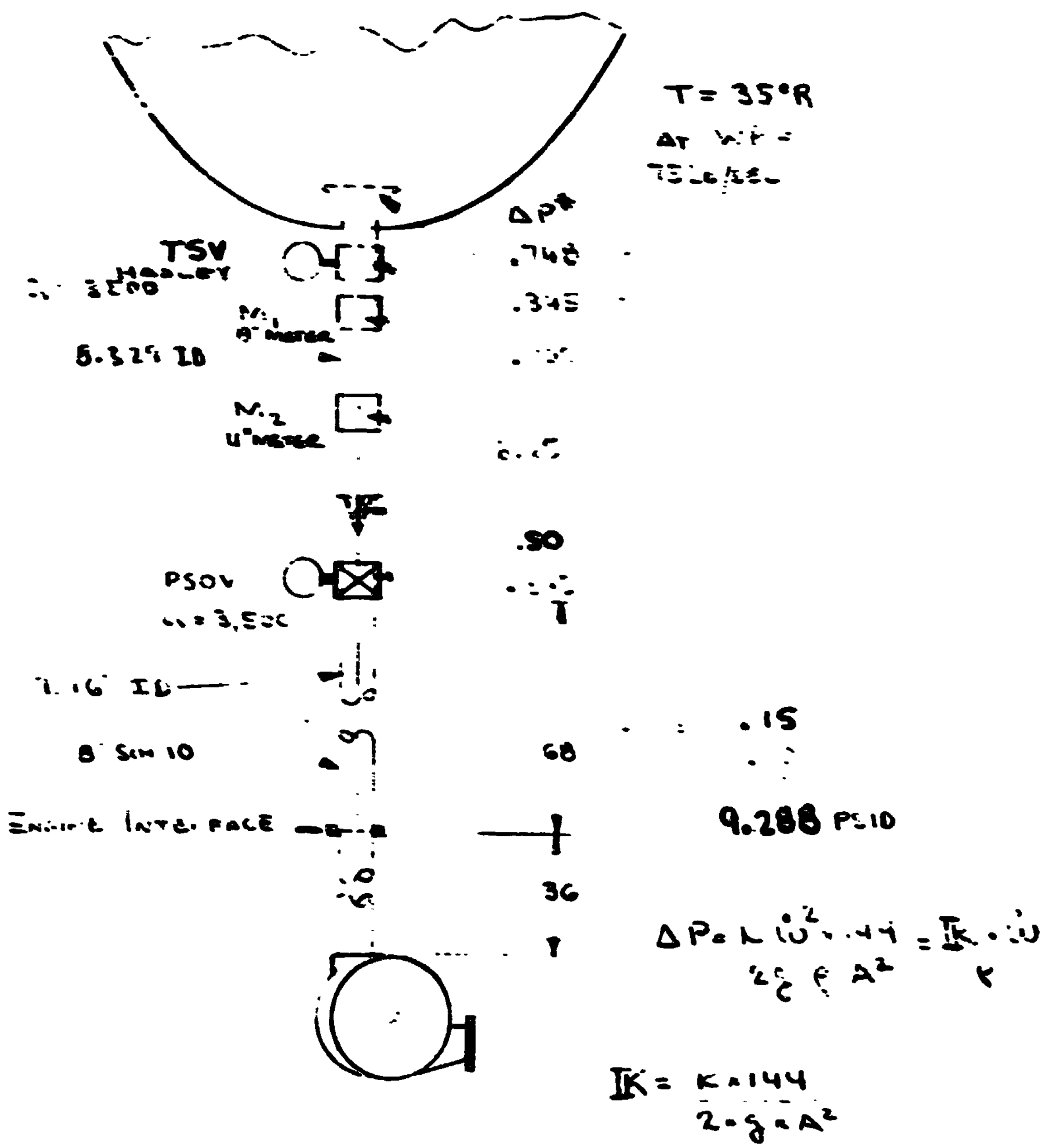

T= 35°R
ΔP*
TSV
.748
.345
PSOV
.50
8.329 ID
.15
8" SCH 10
68
ENGINE INTERFACE
9.288 PSID
36
ΔP= K ẇ² × 144 / 2g ρ A² = K ẇ
K = K × 144 / 2 × g × A²

FIGURE 2

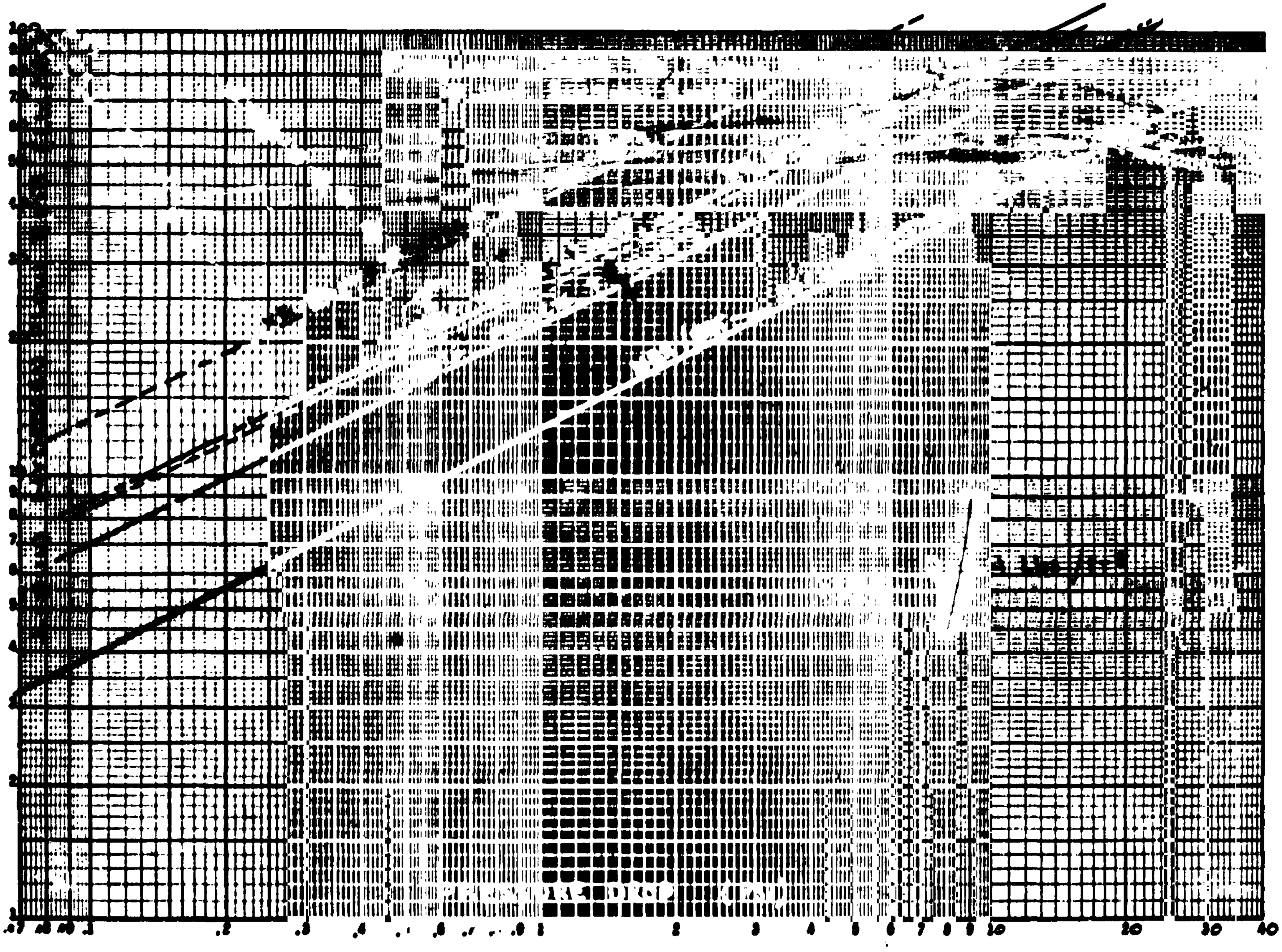
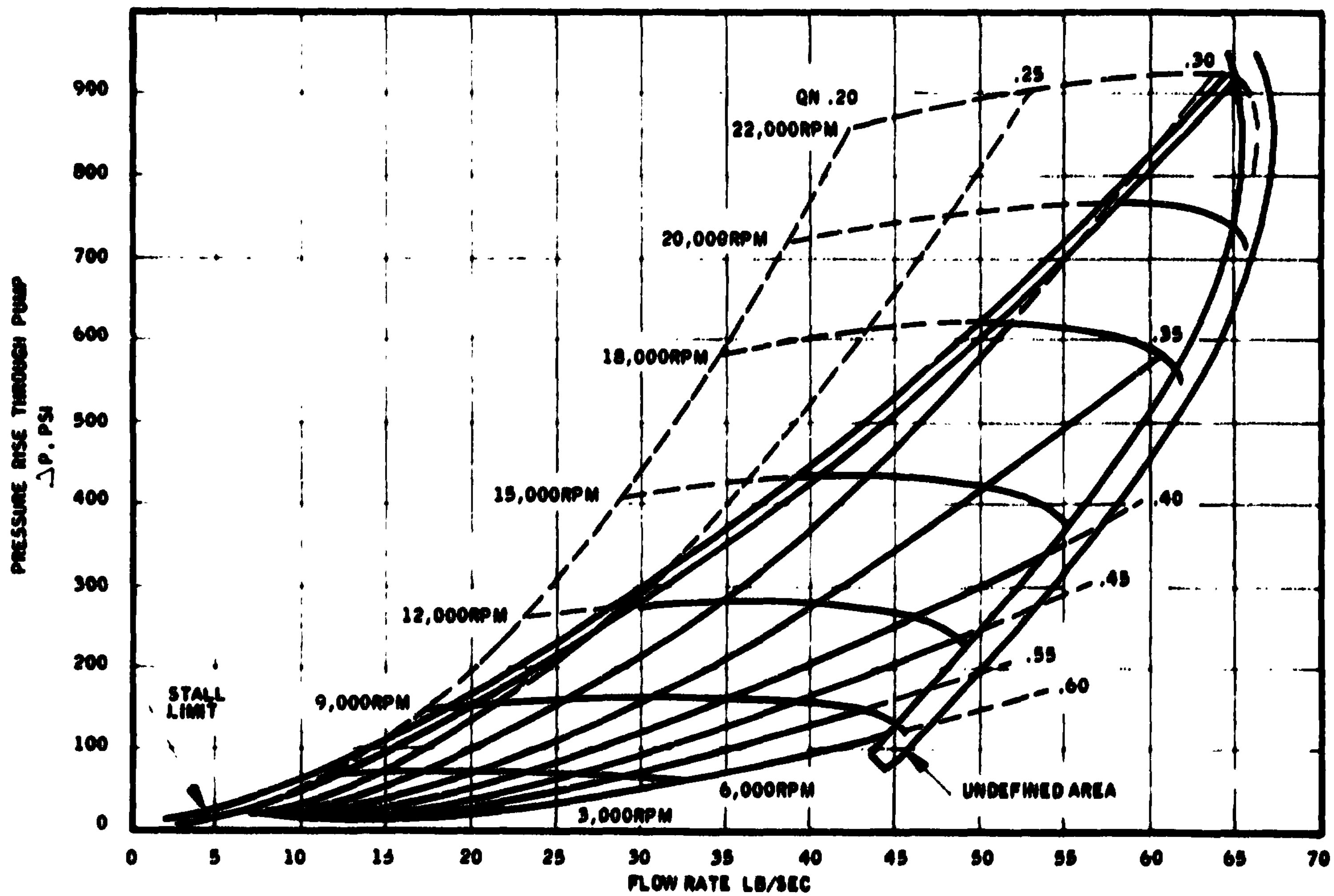
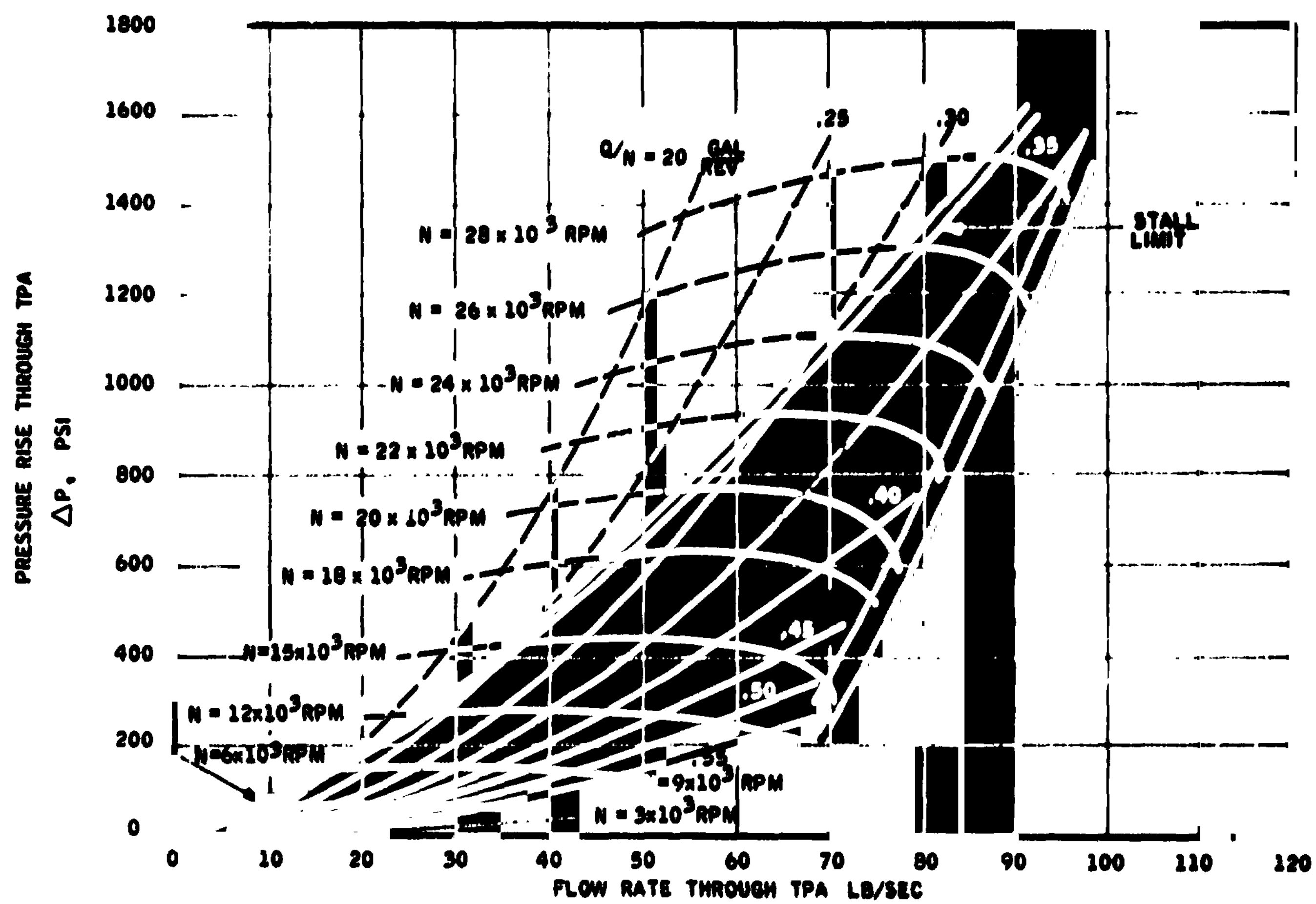


FIGURE 3



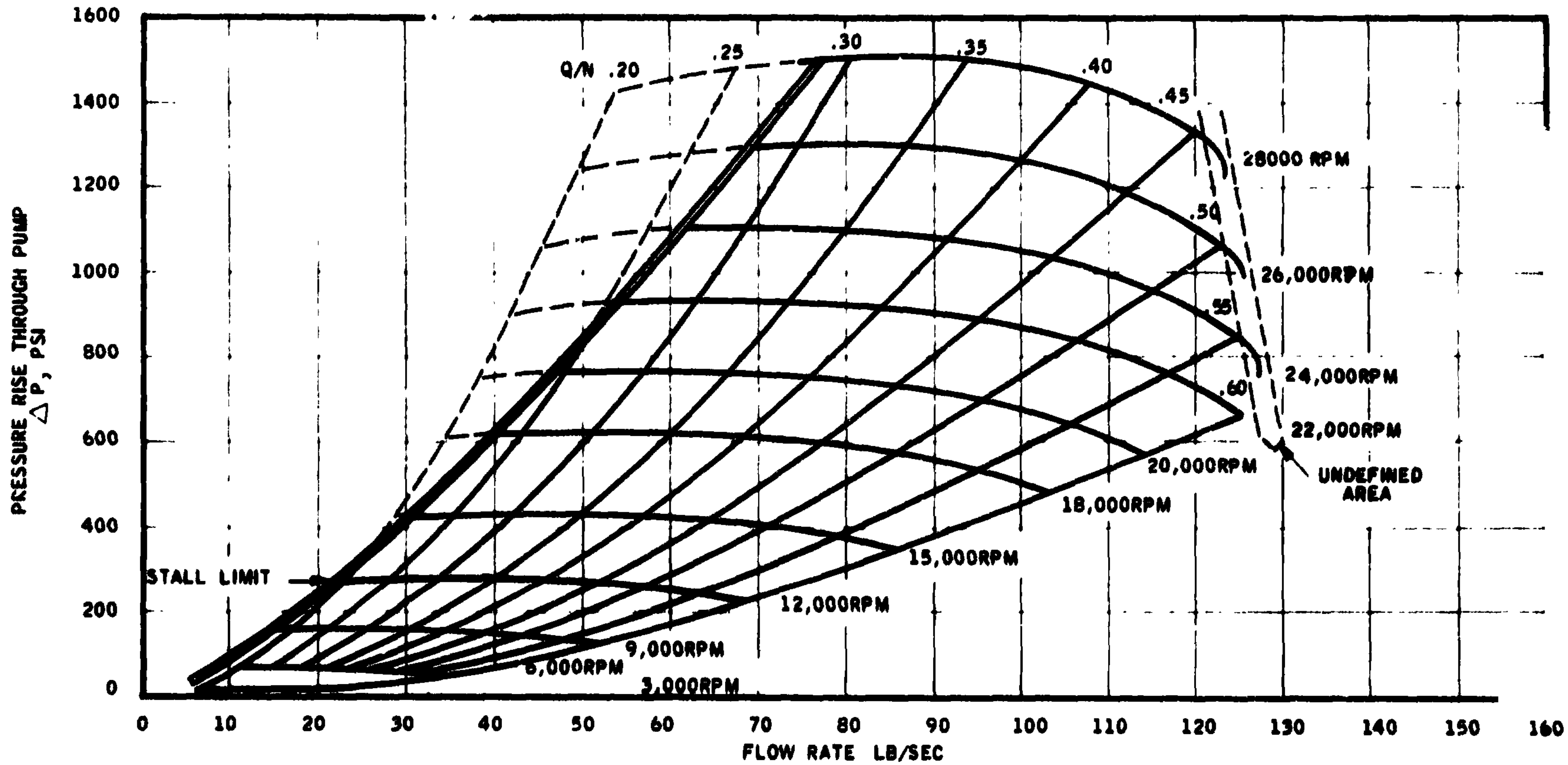
NERVA MARK III MOD 4 PUMP PREDICTED PERFORMANCE
NPSP = 2 PSI DENSITY = 4.33 LB/FT^3

FIGURE 4



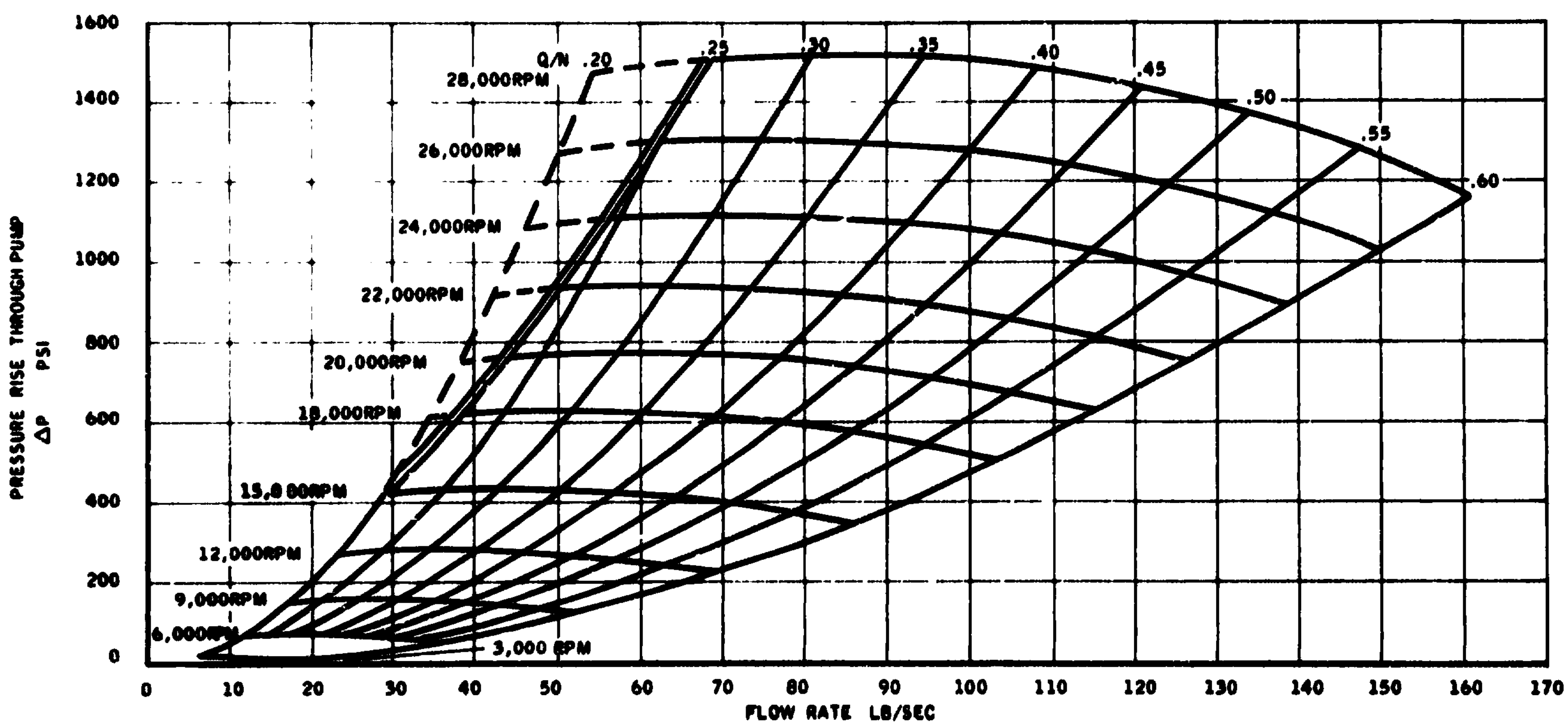
NERVA MARK III MOD IV TURBO PUMP ASSEMBLY PREDICTED PERFORMANCE
NPSP = 5 PSI DENSITY = 4.33 LB/FT ^{3}

FIGURE 5



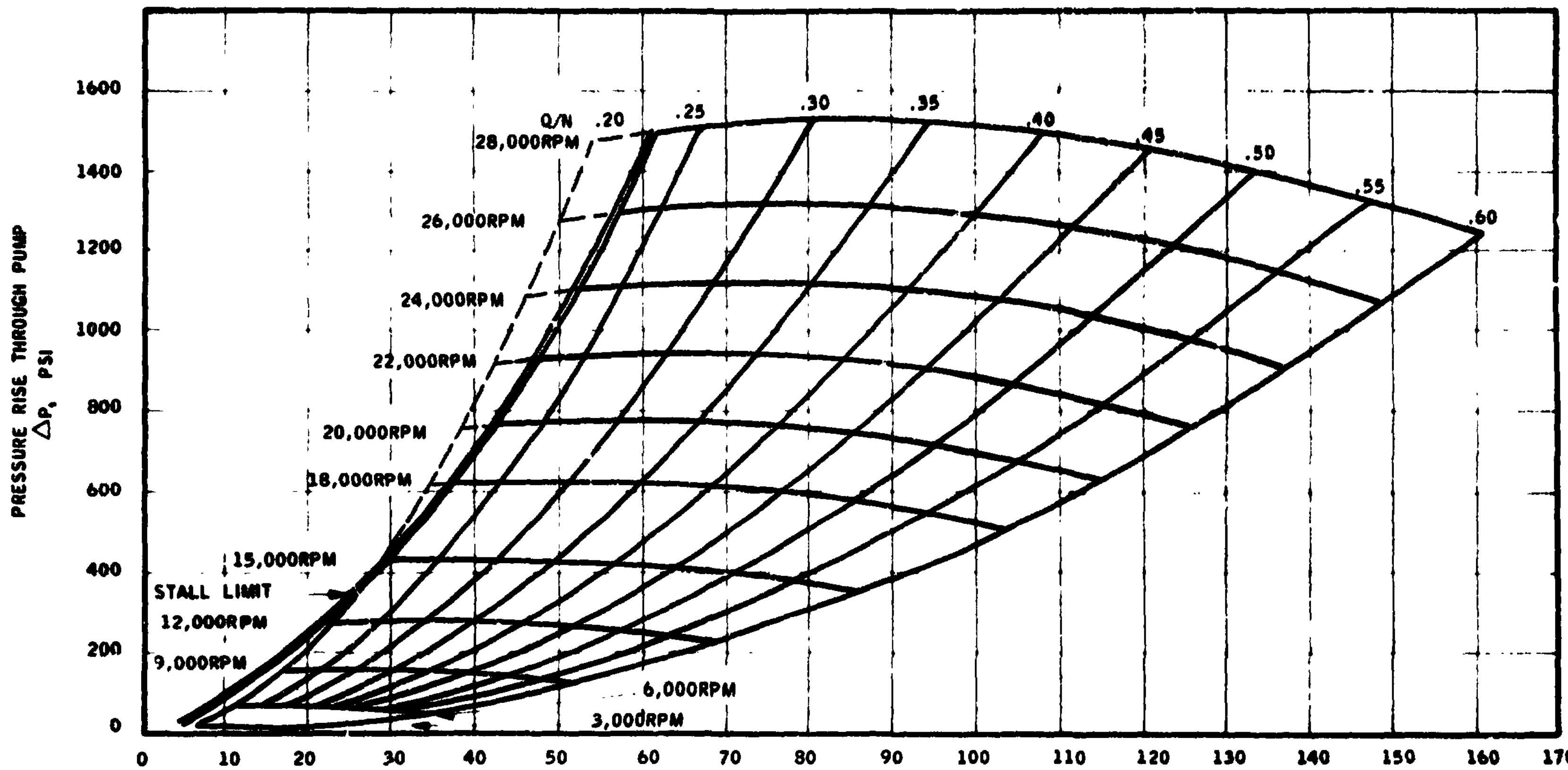
NERVA MARK III MOD 4 PUMP PREDICTED PERFORMANCE
PRESSURE RISE VS FLOW RATE
NPSP = 15 PSI DENSITY = 4.30 LB/FT^3

FIGURE 6



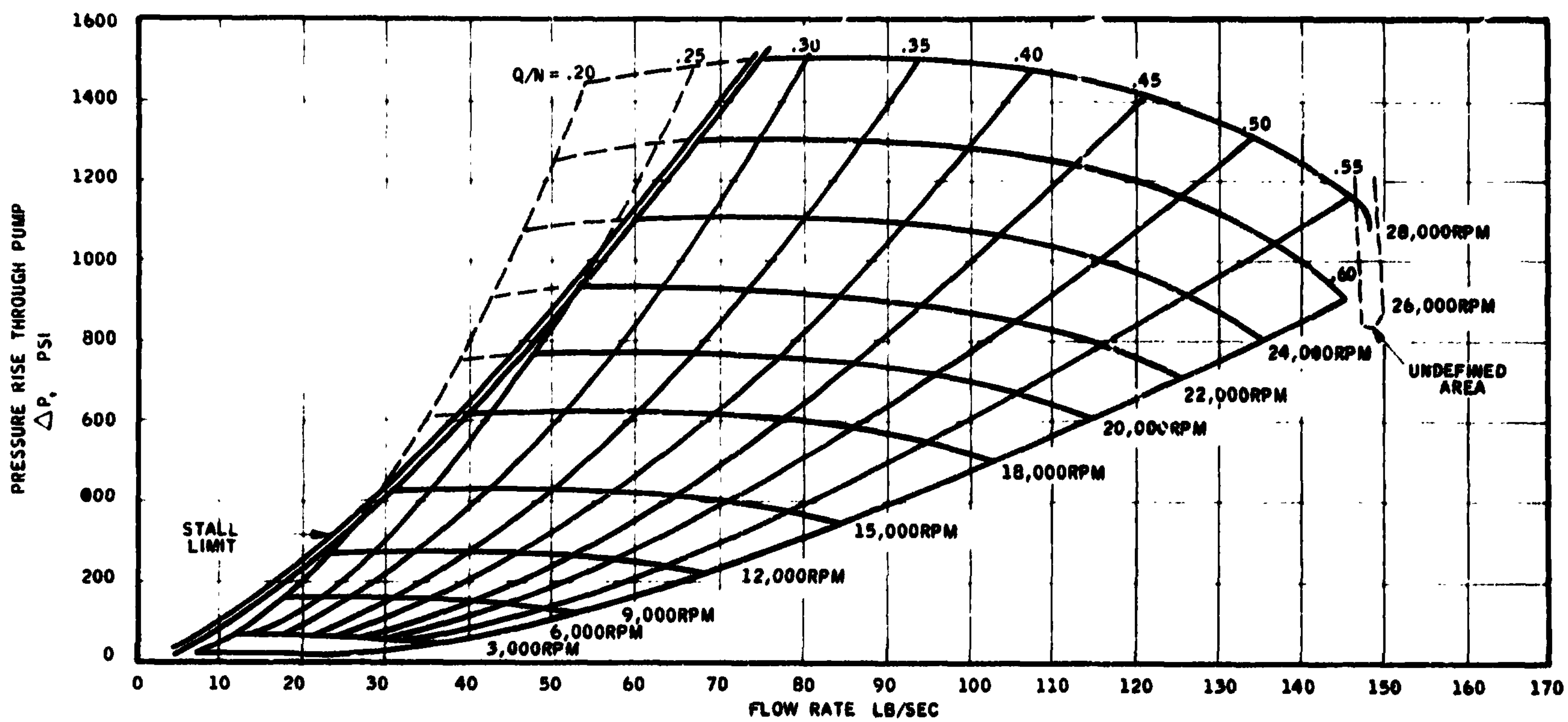
NERVA MARK III MOD 4 PUMP PREDICTED PERFORMANCE
PRESSURE RISE VS FLOW RATE
NPSP = 35 PSI DENSITY = 4.30 LB/FT^3

FIGURE 7



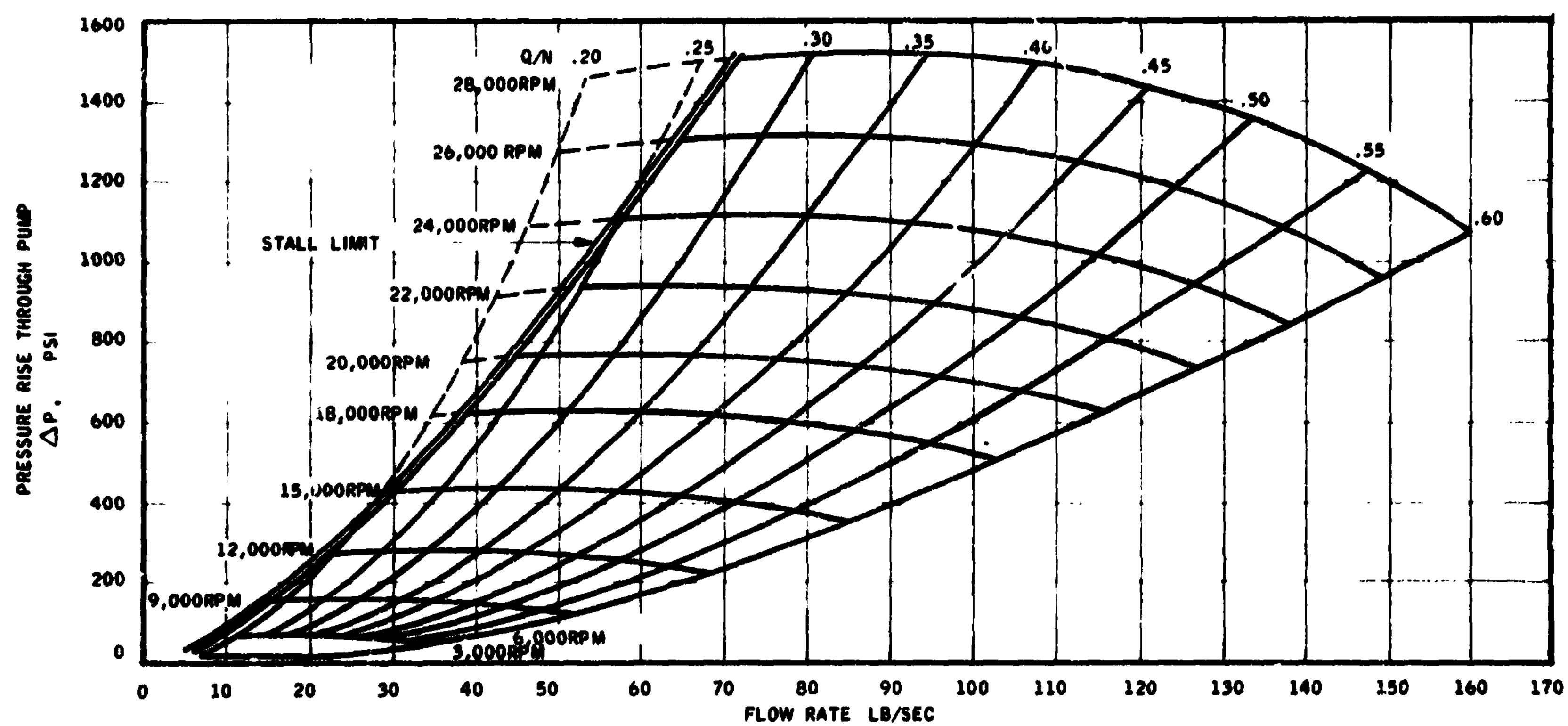
NERVA MARK III MOD 4 PUMP PREDICTED PERFORMANCE
NPSP = 45 - 75 PSI DENSITY = 4.30 LB/FT^3

FIGURE 8



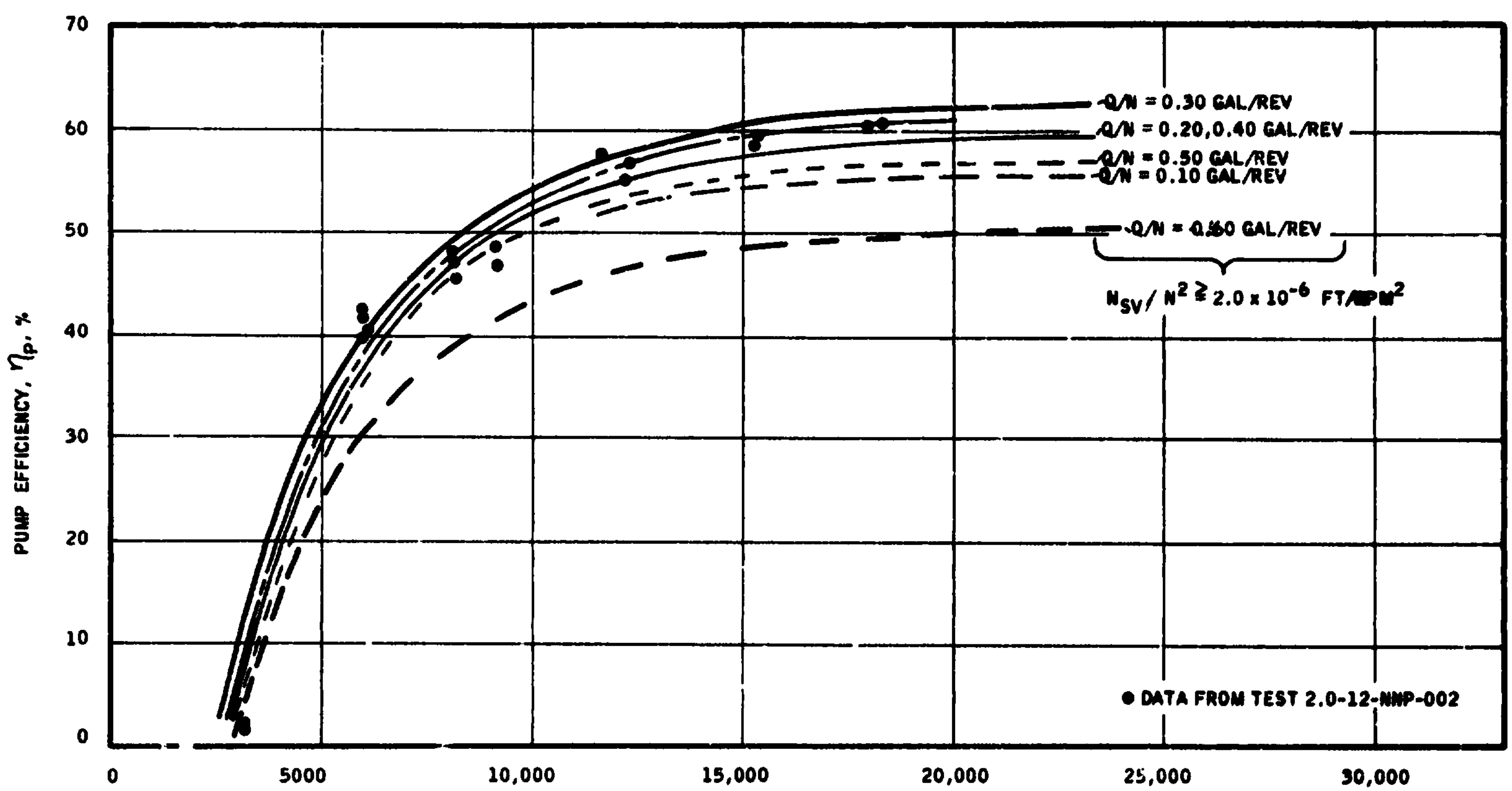
NERVA MARK III MOD 4 PUMP PREDICTED PERFORMANCE
NPSP = 20 PSI DENSITY = 4.30 LB/FT^3

FIGURE 9



NERVA MARK III MOD 4 PUMP PREDICTED PERFORMANCE
PRESSURE RISE VS FLOW RATE
NPSP = 25 PSI DENSITY = 4.30 LB/FT^3

FIGURE 10



NERVA MARK III MOD 4 TURBOPUMP, LH_2 PUMPING PERFORMANCE
PUMP EFFICIENCY VS ROTATIONAL SPEED

FIGURE 11

MARK III MOD 4 TURBOPUMP EFFICIENCY

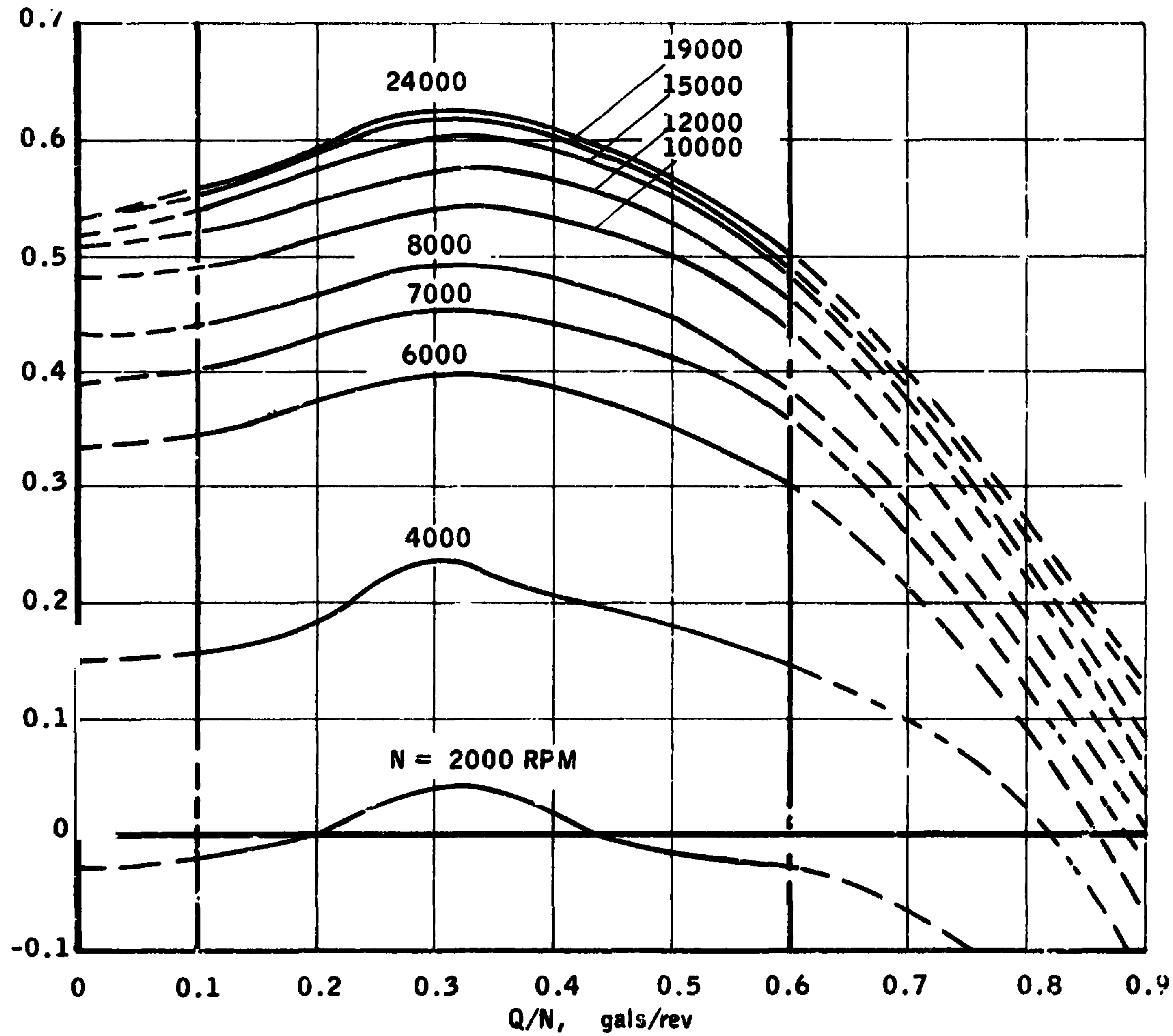


FIGURE 12

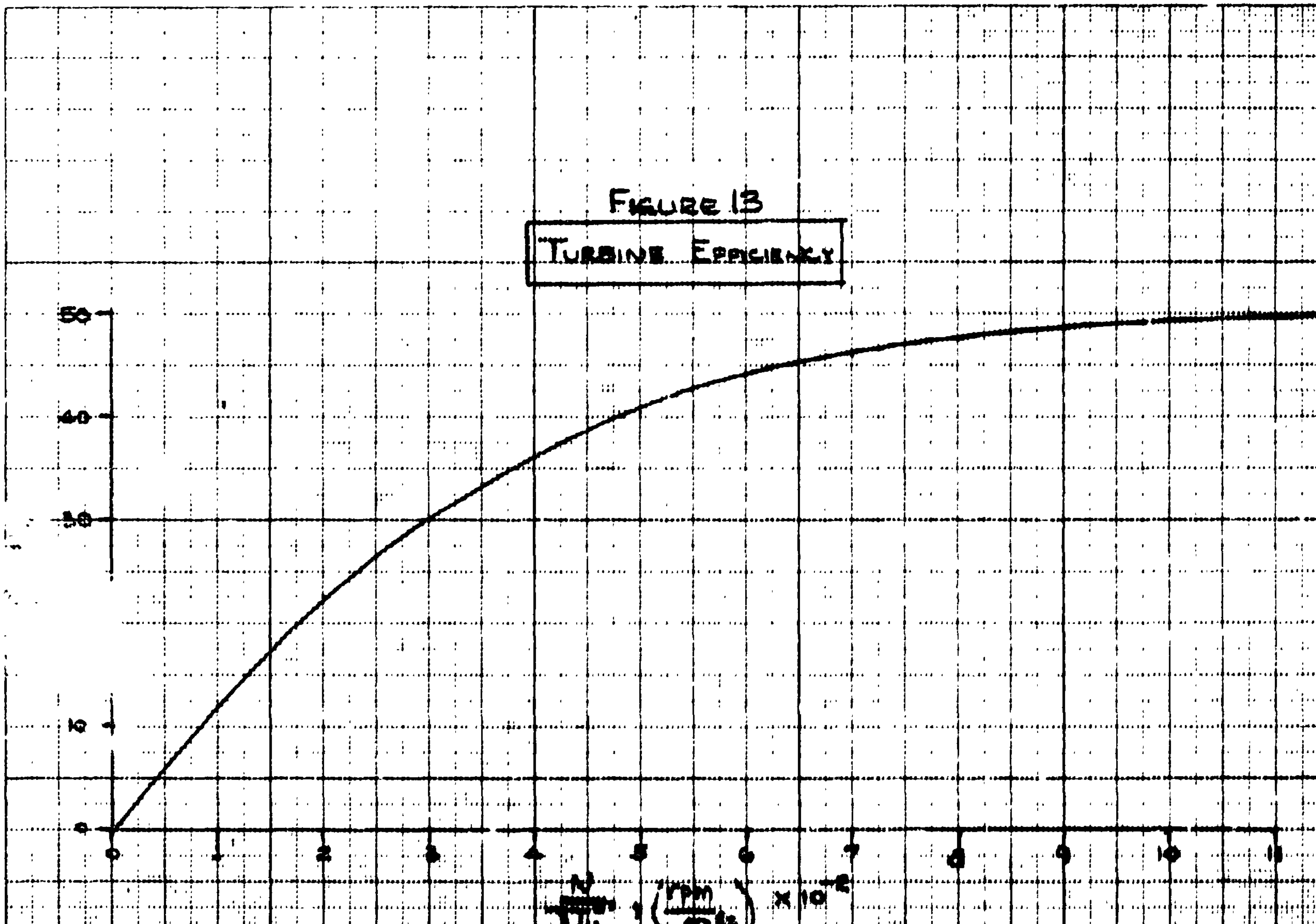
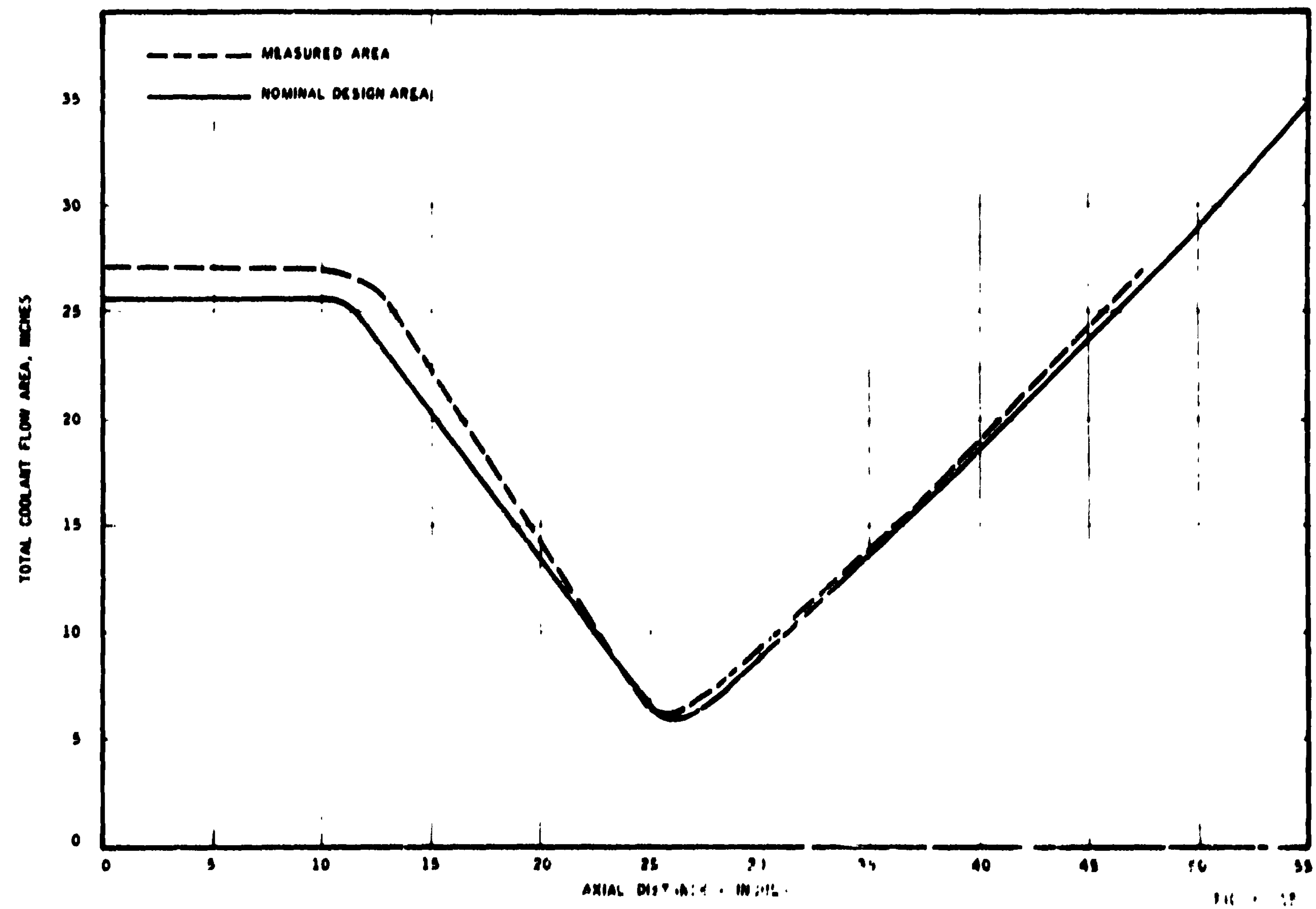


FIGURE 13

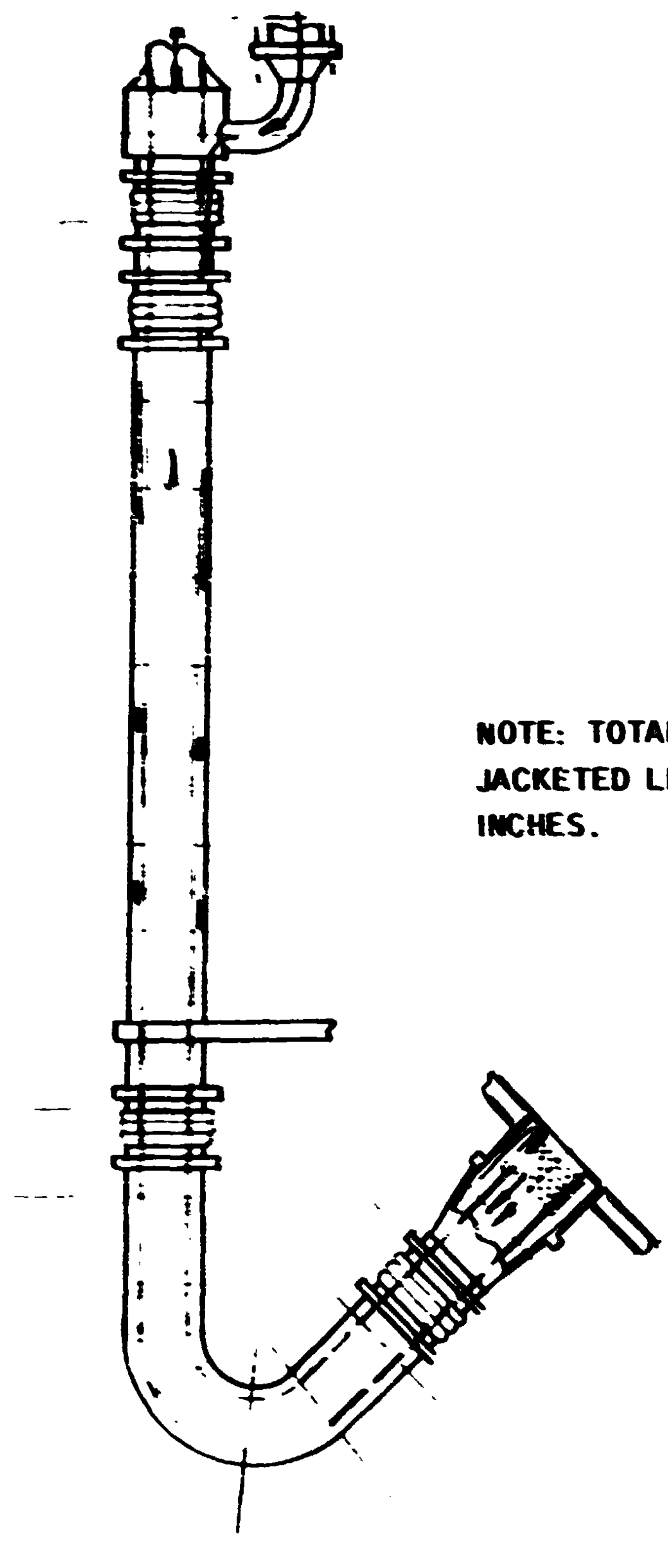
TURBINE EFFICIENCY

Reference: 7450:M0020



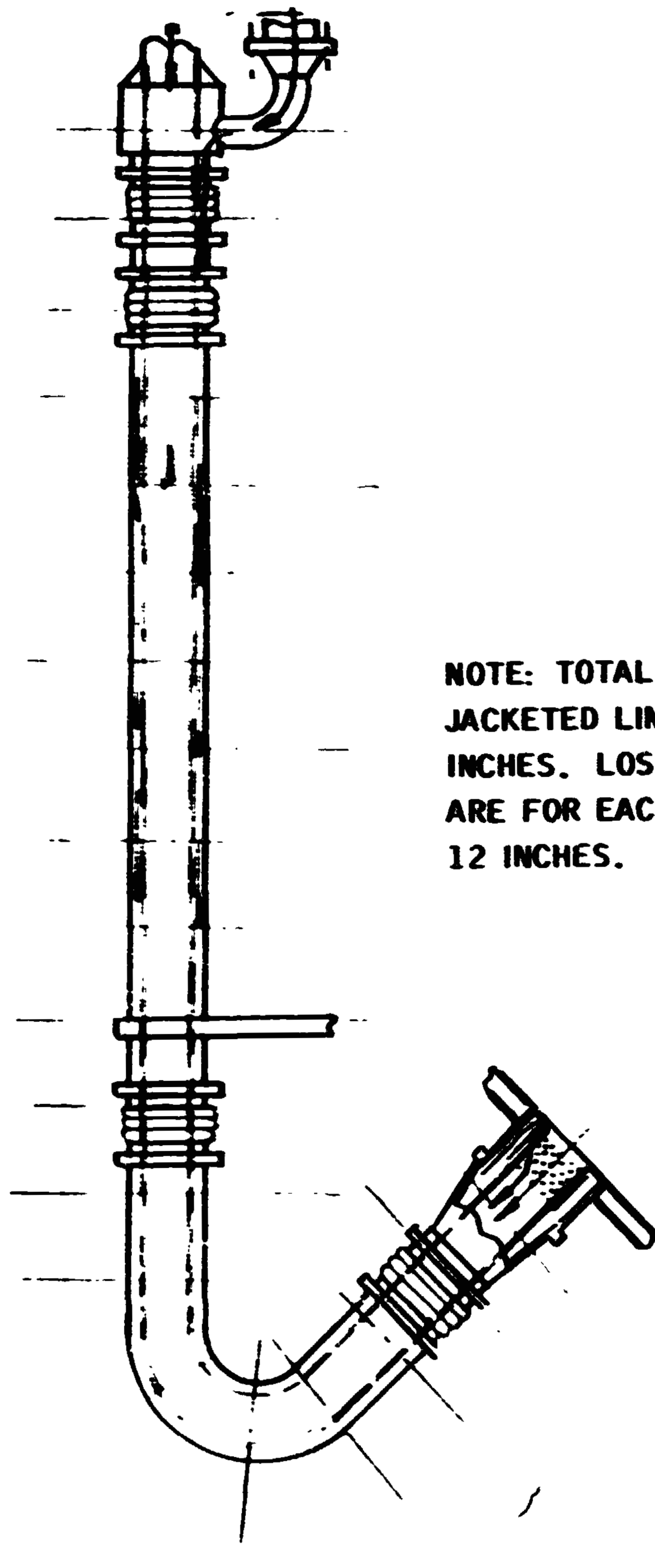
SN 073 NOZZLE COOLANT FLOW AREA VS AXIAL DISTANCE

FIGURE 17
HOT BLEED SYSTEM
CFDTS DIMENSIONS



NOTE: TOTAL LENGTH OF JACKETED LINE IS 120 INCHES.

FIGURE 18
HOT BLEED SYSTEM
CFDTS LOSS COEFFICIENTS



NOTE: TOTAL LENGTH OF JACKETED LINE IS 120 INCHES. LOSS COEFFICIENTS ARE FOR EACH SEGMENT OF 12 INCHES.